Environmental Monitoring of the Fraser River at Prince George. Chemical Analysis of Fish, Sediment, Municipal Sewage and Bleached Kraft Wastewater Samples

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ENVIRONMENTAL MONITORING OF THE FRASER RIVER AT PRINCE GEORGE. CHEMICAL ANALYSIS OF FISH, SEDIMENT, MUNICIPAL SEWAGE AND BLEACHED KRAFT WASTEWATER SAMPLES

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ABSTRACT

Rogers I. H. and H. W. Mahood. 1982. Environmental monitoring of the Fraser River at Prince George. Chemical analysis of fish, sediment, municipal sewage and bleached kraft wastewater samples. Can. Tech. Rep. Fish. Aquat. Sci. 1135: iv + 15 p.

In October 1980 a field study was conducted at Prince George, B.C. by the Environmental Protection Service, Environment Canada. Six species of fish and sediment samples were taken from the Fraser River at four sites upstream of and just below two pulp mill discharges and the main municipal sewage outfall. Wastewater samples from these sources were also collected. All samples were analysed for chlorinated organic compounds.

About 30 chlorinated phenols, acids and neutral compounds were detected in pulp mill wastes and some remain unidentified. These sources also discharge haloforms and volatile sulphur compounds while municipal sewage contains haloforms, chlorinated solvents and toluene. A crude estimate of the total daily loading of chloroform - the major haloform - to the Fraser River at Prince George is about 57 kg. This corresponds to a maximum receiving water concentration of 6.8 ppb in February for 3 km above the confluence with the Nechako River, assuming complete mixing.

No chlorinated organics or resin acids were detected in fish liver samples. Bridgelip suckers contained some compounds that appeared to originate in sewage and some terpene hydrocarbons may have derived from the pulp mills. Isomers of 2-methyldecalin were seen in largescale suckers and diethylene glycol in sediments at the control site. These findings are not readily explained. Other fish analysed were relatively free of organic contaminants except for one sample of Dolly Varden char which contained traces of sewage components.

A sediment sample near a pulp mill discharge also contained diethylene glycol, dehydroabietic acid and the related compound retene, besides a terpene alcohol, tributyl phosphate and dioctyl adipate.

The results indicate the absence of detectable levels of chlorinated organic compounds or resin acids in fish that utilize the river in the area of the wastewater discharges. There appears to be some contamination of river sediments from unknown sources. The quantitation of chloroform levels in the Fraser River is a matter deserving more detailed study because of its carcinogenic properties and a lack of information regarding its persistence and longterm release from chlorolignin in a fast flowing river.

RÉSUMÉ

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Le Service de protection de l'environnement d'Environnement Canada a mené une étude sur le terrain à Prince George (C.-B.) en octobre 1980. Des échantillons de six espèces de poissons et de sédiments ont été prélevés dans le fleuve Fraser, à quatre emplacements en aval et en amont de deux conduites d'évacuation d'usines de pâte et de la conduite de décharge principale des égouts municipaux. Des échantillons d'eaux usées de ces sources ont aussi été recueillis. On a analysé tous les prélèvements pour détecter les composés organiques chlorés.

Environ 30 phénols chlorés, acides et composés neutres ont été décelés dans les effluents des usines de pâte et quelques-uns n'ont pu être identifiés. Ces installations déversent aussi des halogénoformes et des composés soufrés volatils; les effluents municipaux contiennent des halogénoformes, des solvants chlorés et du toluène. La charge quotidienne totale de chloroforme, le principal halogénoforme déversé dans le flueve Fraser à la hauteur de Prince George, est évaluée sommairement à 57 kg. Ceci correspond à une concentration maximale dans les eaux de réception de 6,8 parties par milliard en février, à 3 km en amont de la confluence avec la rivière Nechako, en supposant que le produit se mélange complètement.

Les échantillons de foies de poissons ne renferment aucun composé organique chloré ni acide résinique. Les meuniers de l'ouest contiennent quelques composés qui semblent provenir des eaux d'égout et quelques hydrocarbures terpéniques qui peuvent émaner des usines de pâte. Des isomères de méthyldécaline-2 et du glycol diéthylique ont été détectés dans les meuniers à grandes écailles et dans les sédiments de l'emplacement type, respectivement. On n'explique pas facilement ces découvertes. D'autres poissons analysés étaient relativement exempts de contaminants organiques sauf pour en échantillon de Dolly Varden qui contenait des traces de composants retrouvés dans les eaux usées.

Un échantillon de sédiment prélevé près d'une conduite d'évacuation d'usine de pâte contenait aussi de glycol diéthylique, de l'acide déhydroabiétique et du rétène, un composé apparenté, ainsi qu'un alcool terpénique, du phosphate de tributyle et de l'adipate de dioctyle.

Les résultats montrent l'absence de niveaux discernables de composés organiques chlorés ou d'acides résiniques dans les poissons qui habitent la partie du fleuve aux environs des points de déversement des eaux usées. Il semble y avoir une certaine contamination des sédiments de source inconnue. La quantification des niveaux de chloroforme dans le fleuve Fraser mérite d'être étudiée de façon plus détaillée car ce produit est carcinogène et l'on manque de données au sujet de sa rémanence et de son dégagement à long terme de la chlorolingine dans une rivère à débit rapide.

INTRODUCTION

Prince George, located at the geographical centre of British Columbia at the confluence of the Fraser and Nechako Rivers, relies heavily on the forest industry for employment and has a current population of about 73,000. Both rivers constitute important migration and or spawning areas for sockeye and chinook salmon stocks. In 1979 more than half a million adult sockeye salmon passed the confluence point en route to spawning gravel beds in the Nechako, Stuart and Upper Bowron Rivers. Because these fish travel farther to their spawning grounds than any other anadromous stocks in the Fraser River and are subject to various environmental stresses such as high water temperatures or infestations of pathogenic bacteria, there is always concern about levels of prespawning mortality which could be critical to the perpetuation of the population. Such effects are usually caused by a combination of factors (Williams 1973; Williams et al 1977) and stress due to chronic exposure to toxic substances of industrial origin could accentuate an existing problem.

Three mills at Prince George manufacture liner board and fully bleached kraft pulp and are located within a few kilometers of each other (Figure 1). They discharge a daily volume of about 294,000 m^3 of wastewater to the Fraser River. All this waste receives secondary treatment in two aerated stabilization basins before discharge and there have been very few acute toxicity failures in routine monthly bioassay tests with rainbow trout in recent years.

This does not mean that toxic pollutants were absent from the treated wastewater but only that their concentrations were reduced below what would have caused half the test fish to die within the 96 hr test period. The bioassay results give no indication of the presence of symptoms of chronic toxicity.

The joint aerated stabilization basin that treats the wastewaters of Intercontinental Pulp and Prince George Pulp and Paper Companies has been described (McDonald 1978). This lagoon has a capacity of 245 million U.S. gallons and a calculated retention time of 4.3 days. Subsurface aeration of the wastewaters is achieved by air pumped through perforated pipes installed on the bottom, resulting in a very even distribution of the air bubbles throughout the lagoon. The condition of the river is routinely monitored by provincial authorities under a contract arranged with a private company. However, no analyses for organic pollutants are performed.

The Environment Protection Service of the Department of Environment considered that chemical analyses of fish samples from the Fraser River should be conducted to ensure that bioaccumulation of toxic substances was not occurring. Accordingly a field survey was mounted in October 1980 and samples of mountain whitefish (Prosopium Williamsoni), Dolly Varden trout (Salvelinus malma), redside shiner (Richardsonius balteatus), largescale sucker (Catostomus macrocheilus), bridgelip sucker (Catostomus columbianus) and chinook salmon fry (Oncorhynchus kisutch) were taken in beach seines from four stations (Figure 1). The livers of 21 of these fish were analysed together with wastewater samples collected from the pulp mills and 2 samples from municipal sewage treatment plants. We report now the results of these investigations.

EXPERIMENTAL METHODS

SAMPLE COLLECTION

Four stations were sampled in the Fraser River during the period September 30 to October 1, 1980 by biologists from the Environmental Protection Service (see Figure 1). The control site (R_1) was at Shelley, which is upstream of the pulpmills and industrial activity at Prince George. Site R_2(N) was downstream of the Northwood Pulp Ltd. outfall but upstream of the Prince George/Intercontinental Pulp Ltd. outfall. Station R_2(S) was downstream of both pulpmill outfalls but upstream of the Nechako River confluence. The fourth station (R_3) was downstream of the pulp mill and municipal sewage discharges. Fish were taken from the river by beach seine at all four sites. Livers were removed and placed in clean glass jars, frozen in dry ice, and returned to the laboratory for analysis. Sediment samples were collected at sites R_1 and R_2N.

The organisms collected for analysis are detailed in Table 1. Besides those listed, redside shiners and chinook salmon were taken but not chemically analysed.

PREPARATION OF EXTRACTS FOR ANALYSIS

Wastewater samples

Single grab samples of sewage (1 l) from Prince George STP and the Airport STP (see Fig. 1) were acidified to pH2 with sulfuric acid and extracted three times with ether (100, 75, 50 ml). The combined ether extracts were evaporated in a rotary evaporator, the residue methylated with diazomethane and transferred to a vial, dissolved in methylene dichloride, for analysis. Treated pulp mill wastewater samples were extracted in a similar manner.

Four grab samples of treated pulpmill wastewater (1 l) were made basic (pH10) and extracted three times with ether in a separating funnel. The ether extracts were combined and reduced in volume to 1 ml in a Kuderna Danish apparatus to yield a base/neutrals extract. The pulp mill wastewaters were then acidified (pH2) and re-extracted with ether. The combined extracts were similarly reduced in volume to 1 ml, esterified with diazomethane in ether and the final volume again adjusted to 1 ml in preparation for analysis.

Samples of treated pulpmill wastewater (1 l) were also analysed using an acetylation procedure (Voss et al, 1981) which converts phenolic compounds to their acetate derivatives. Typically potassium carbonate (10 g) was added to the wastewater sample followed by acetic anhydride (10 ml). After standing 1 hour at room temperature, the mixture was extracted three times with hexane (50, 50, 25 ml). The combined hexane extract was reduced in volume to 1 ml using a Kuderna Danish apparatus.

Sediment samples

Two sediment samples (30 g) were air-dried in the laboratory and were extracted in an all-glass sohxlet apparatus for 48 hr using methylene chloride. Extracts were evaporated to dryness in a rotary evaporator and the residues methylated with diazomethane.

Tissue samples

Liver and gallbladder tissue samples (0.5 to 4.5 gm) were disintegrated in hexane/acetone (2:1, 25 ml) using a Brinkmann polytron. The homogenate was separated using a centrifuge and the solvent layer recovered (10 ml), the combined extracts concentrated and methylated with diazomethane and the final volume adjusted to 1 ml.

ANALYTICAL PROCEDURES

Gas Chromatography - Mass Spectrometry (GC-MS)

Extracts were analysed on a Hewlett Packard Model HP 5992B GC-MS bench top instrument operated in the peakfinder mode and calibrated internally against perfluorotributylamine. The split ratio was 10:1 and a wide-bore capillary glass column (OV-101, 25 m) was used. The temperature was programmed from 50° to 250° C at 10° C/min. with a helium carrier gas flow rate of 2 ml/min. The injection port temperature was maintained at 200° C.

Purge and trap analysis

Two samples of pulp mill wastewater and two of municipal sewage (50 ml) were purged for 10 minutes with helium gas and the volatiles collected on a 15.2 cm by 6.35 mm Tenax trap. After purging was complete the carrier gas flow through the trap was reversed, the trap heated and the volatiles passed into the GC-MS instrument where they were analysed after passing through a 183 cm by 2 mm I.D glass column packed with 0.2% Carbowax 1500 on 80-100 mesh Carbopack C. An external standard containing methylene chloride, chloroform and carbon tetrachloride at known concentrations was prepared freshly each day when volatiles were to be analysed. Chloroform concentrations were calculated on the basis of measured total ion currents in the wastewater samples relative to the external standard solution for the chloroform peaks.

RESULTS AND DISCUSSION

About 30 low-molecular-weight chlorinated organics were observed in treated wastewater samples from the two pulp mill discharges (Table 2 and Table 3). Besides the normal range of chlorinated phenols, guaiacols and catechols (Voss et al 1981; Lindstrom and Nordin 1976) and the chlorinated dehydroabietic acids (Leach and Thakore 1975; Holmbom and Lehtinen 1980) we observed chlorinated short-chain carboxylic acids including di- and trichloroacetic acid, di- and trichloroacrylic acid and dichloromaleic acid. Isomers of chlorinated benzoic acid and phenylacetic acid were also detected. It is believed that these latter compounds arise as a result of the biological oxidation of other chlorinated compounds - perhaps including chlorinated lignin - during secondary treatment. A number of unidentified chlorinated compounds were also detected.

Resin acids are important fish-toxic components of pulp mill wastewaters and it is largely to control releases of these compounds that secondary treatment has been installed at kraft mills in the British Columbia Interior. Using dehydroabietic acid as an external standard, total resin acid concentrations of around 10 ppb were estimated in 1981. This indicates an apparent reduction of about three orders of magnitude in the concentration of such compounds as a result of secondary treatment. We are unable to measure concentrations of chlorinated compounds directly in the wastewater for lack of suitable standards.

Besides the pulp mills, chlorinated compounds might enter the Fraser River at Prince George as a result of the discharge of chlorinated sewage. The chlorinated compounds might be formed during the disinfection process or they could already be present in the wastewater due to the release of chlorinated solvents from industrial or household activities. We analysed single grab samples from the main Prince George municipal sewage treatment plant and the Airport/Blackburn treatment centre (see Figure 1). These samples did not contain detectable levels of chlorinated substances in the extractables but purge and trap analyses showed the presence of methylene chloride, chloroform and trichloroethylene in the former and chloroform, dimethyl disulphide and dichlorobenzene in the latter samples. The presence of such compounds is in keeping with many published studies (see for example Keith et al, 1976). However, dichlorobenzene is not always detected. It is used for odour control in public lavatories and has been detected in sediments in the vicinity of the Iona Island Sewage Treatment Plant outfall, which serves a major part of the City of Vancouver (Keith and Lewis 1979).

A sample of treated Prince George Pulp and Paper/Intercontinental Pulp wastewater contained methylene chloride, chloroform, dimethyl sulphide, dimethyl disulphide and toluene, when analysed by the purge and trap technique. Upon comparison with an external standard, the concentration of chloroform was estimated at 197 ppb and methylene dichloride at 31 ppb. Assuming similar concentrations are present in Northwood Pulp and Paper Ltd. wastewater, mean monthly water flow data for the two mills would indicate a crude estimate of 57 kg of chloroform and 9 kg of methylene chloride discharged to the river on a daily basis. There are additional amounts discharged in municipal sewage but these are of considerably lower concentration and flow.

Data available for mean monthly flow of the Fraser River at Shelley, B.C. in 1980 indicate that the minimum flow occurred in February when a monthly average of 97.1 m^3/sec was recorded (Anon, 1981). This translates into a chloroform concentration in river water of 6.8 ppb assuming perfect mixing. In actual fact this would have applied to a stretch of river of only about 3 km because the confluence with the Nechako River added a further 49.5 m^3/sec of dilution water at that period. Chloroform is considered a human carcinogen and is on the United States Environmental Protection Agency list of 129 Priority Pollutants. Twenty-seven-day LC_{50} values using rainbow trout indicated that chronic toxicity occurred at concentrations down to 1240 ppb (Anon 1980). This would indicate there is little cause for concern regarding the effect of the pulp mill discharges on aquatic life. However, for protection of human health, the criteria call for zero exposure because there is no recognized safe level for a human carcinogen. Achieving a zero concentration level is not considered to be feasible and so the concentrations of chloroform corresponding to several incremental lifetime cancer risk levels have been estimated using data obtained from the exposure of female mice to chloroform in drinking water. In order to keep the individual lifetime risk below 10^{-5} (one death per 100,000 of population) the drinking water concentration of chloroform should be less than 1.90 ppb according to the ambient water quality criteria. Fortunately there are no intakes for drinking water in that stretch of the river.

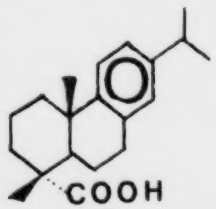
Available water flow data (Anon 1981) show that a peak flow of 1680 m^3/sec occurred at Shelley, B.C. in May, 1980 and the yearly average flow at that point was 728 m^3/sec. These water flows would reduce the chloroform concentrations below the two pulp mill outfalls and above the confluence with the Nechako River to 0.39 and 0.91 ppb respectively.

In some unpublished experiments conducted in this laboratory we recently found that chloroform generation can continue for a protracted time period from treated pulp mill wastes. Thus samples, that had been purged to remove chloroform, were stored in the purge tube in a cold room for several days and then repurged. More chloroform was detected in the mass spectrometer. We found that the phenomenon continued for at least three weeks. This indicates that chlorolignin, which contains most of the organically bound chlorine from the bleach plant (Lindstrom et al 1981), is capable of releasing chloroform to the environment for some time after it has left the secondary treatment pond. Moreover chlorolignin residues are recalcitrant to biological breakdown. In a lake in Finland 25-year old layers of benthic sediments, collected at a distance of 5 km downstream from a kraft pulp mill, contained more than 10 mg of chlorine /gm of dry matter (Salkinoja-Salonen et al 1981). Chloroform has been widely detected in Finnish lakes below bleached pulp mill discharges (Toivanen 1981). These various studies do not necessarily imply that there is a public health problem for downstream water users on the Fraser; taken together however it would seem that the need exists for a detailed assessment of the present levels in the river below Prince George and Quesnel.

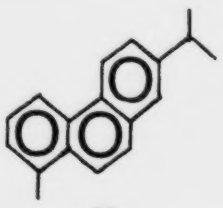
Methylene chloride is not a human carcinogen and is not on the United States Environmental Protection Agency list of 129 Priority Pollutants. The discharge of this compound at the levels we recorded is believed to be inconsequential.

Compounds identified in liver tissue from four fish species and in sediment samples are summarized in Table 4. Only two sediment samples were analysed. That from Shelley - the control site - was heavily contaminated with diethylene glycol. There is a sawmill near Shelley but this seems to be an unlikely source for diethylene glycol which is used as a de-icing agent (Evans and David 1974). Possibly the compound may have entered the river as a result of snow removal operations on the adjoining road or railway systems.

The other sediment sample analysed was taken below the Northwood Pulp Ltd. outfall and it also contained diethylene glycol, although in apparently lesser amounts. Two other related compounds were observed. (Ethylene glycol-related compounds usually give rise to prominent m/e 45 ions, which otherwise are not often encountered). The compounds tributyl phosphate and dioctyl adipate may arise from mill sewage or the use of specific detergents or other additives. Dehydroabietic acid (I) is a common resin acid and its structure is obviously closely related to the compound 1-methyl-7-isopropylphenanthrene (II) which is probably a metabolite formed by the action of anaerobic bacteria on dehydroabietic acid.



I



II

This compound is also known as retene and is commonly found in organic-rich sediments (Simoneit 1977). The other substance - 1,hydroxyiso-carvomenthol is a monoterpene alcohol and probably a rearrangement product from a naturally occurring compound present as a wood extractive.

Largescale and bridgelip suckers are bottom-feeding fish which consume amongst many items the larvae of aquatic insects, and graze on attached algae. It was considered that such animals would be more likely to exhibit bioconcentration from polluted sediments than would the other species collected. Samples of largescale sucker were available from three sites and bridgelip suckers were taken at all four sites. All contained diethyl phthalate in their liver tissue indicating that this substance is probably widely distributed in the study area. Phosphate esters were seen at sites below both pulp mills and below the sewage outfall in bridgelip suckers but were not detected in largescale suckers. Unknown phenols and monoterpenes were observed in fish from the vicinity of both pulp mill outfalls. Phenylacetic acid and glutaric acid were observed in bridgelip suckers from the area below the municipal sewage outfall and are commonly observed components of municipal sewage in our recent studies at Iona Island and Annacis Island Sewage Treatment Plants servicing the Greater Vancouver Regional District, B.C.

An unexplained finding was the presence of isomers of 2-methyldecalin in both types of suckers from the control site at Shelley. We do not know to what degree these fish travel in the river. We also do not know the source of

the methyldecalins or what these compounds are used for. Decalin itself is used as a solvent for naphthalene deposits in gas pipelines, for asphalt, paints, printing inks and waxes. It is also a component of motor fuel and lubricants (Gaydos 1981).

Although no chlorinated compounds or known pollutants were identified in whitefish liver tissue samples, those from the control station and the site below both pulp mills gave rise to a number of small peaks with prominent m/e 45 ions suggesting that they may have been metabolic products of some type related to the presence of de-icing compounds such as diethylene glycol in river sediments. Both specimens of Dolly Varden char analysed contained succinic acid which may be a normal metabolic product in this species. However, the sample from the site below both pulp mills contained, in addition, phenylacetic acid and trimethyl phosphate, probably related to sewage pollution and N,N-diethylisopropylamine. The latter compound may also be a normal metabolite, although it was not detected in the fish from the other site.

There is no information on movements within the study area of the various fish species collected during the survey and no record is available as to chemical spills or other specific events that may, in the past, have allowed entry of chemical pollutants into the river system. Because the fish may be quite mobile it is not possible to relate bodyburden chemicals to individual wastewater dishcharges. However, the wastewater samples analysed represent all the major continuous outfalls in the general area of study. Other sources not included are minor volume sewage discharges and stormwater outfalls.

The results of the study appear to indicate the absence of any significant present level of bioaccumulation of toxic organic chemicals in the Fraser River at Prince George. The compounds detected in the internal organs of fish taken from the river are not likely to have effects on humans at the apparently low ppb concentrations observed. The fate of chloroform discharged to the river as a component of treated pulpmill wastes and municipal sewage probably merits a more detailed investigation.

ACKNOWLEDGMENTS

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Table 1. Organisms* Submitted for Chemical Analysis.

Site	Collected	Fork length cm
R 1	1 W	20.5
	1 L	37.5
	2 B	27.5 and 28.5
R 2 (N)	1 W	9.5
	2 L	32 and 25.5
	1 B	28.0
R 2 (S)	2 V	27.5 and 42.5
	4 W	8.5 to 17.0
	2 L	22.5 and 29.5
	2 B	30.0 and 31.5
R 3	1 V	23.0
	1 W	21.5
	1 B	32.0

* W = mountain whitefish
L = largemouth sucker
B = bridgelip sucker
V = Dolly Varden char

Table 2. List of compounds identified in Prince George Pulp and Paper/Intercontinental Pulp treated wastewater samples.*

Dimethyldisulphide	
Dichloroacetic acid	Behenic acid
Trichloroacetic acid	Monochlorodehydroabietic acid
Carbon tetrachloride	Tricosanoic acid
Dichloroacrylic acid	Dichlorodehydroabietic acid
Dimethyl trisulphide	Lignoceric acid
Trichloroacrylic acid	Cresol
Benzoic acid	Xylenol (3 isomers)
Dichloromethyl methyl sulphone	guaiacol (2 isomers)
Phenylacetic acid	dichlorophenol
Salicylic acid	trichlorophenol
Dichloromaleic acid	dichloroguaiacol
Chlorobenzoic acid (2 isomers)	dichlorocatechol
Chlorophenylacetic acid (2 isomers)	trichlorocatechol
Dichlorobenzoic acid	tetrachlorocatechol
3-Acetoxyphenylacetic acid	C_{10} Hydrocarbon
4-Hydroxy-2,6-dichlorobenzoic acid	α-phellandrene
Trichloroguaiacol (2 isomers)	butylbenzene
Tetrachloroguaiacol	caproic acid
Palmitic acid	phthalic acid
Sandaracopimaradiene	myristic acid
Margaric acid	C_{18} hydrocarbon
Linoleic acid	7-oxodehydroabietic acid
Oleic acid	abietatetraenoic acid
Stearic acid	
Pimaric acid	
Isopimaric acid	
Dehydroabietic acid	
Abietic acid	

* - plus 45 unknown compounds

Table 3. List of compounds identified in Northwood Pulp and Paper treated wastewater samples.*

dimethyl disulphide	caproic acid
cumene	trichloroacrylic acid
methyl isopropyl cyclohexadiene	dichloromaleic acid
p-cymene	chlorophenylacetic acid
4-(2-propenyl)-dihydrofuran	isopropylbenzoic acid
γ- terpinene	dichlorobenzoic acid
guaiacol (2 isomers)	phthalic acid
acetylthiophene	Hydroxyacetoxyphenylacetic acid
dichloromethyl methyl sulphone	palmitic acid
dipropylcyclohexenone	oleic acid
camphor	isopimaric acid
2-propionylthiophene	abietatetraenoic acid (2 isomers)
methyl ethyl phenol	dehydroabietic acid
dihydroxyacetophenone	abietic acid
4-tertiarybutyl-2-methoxyphenol	7-oxo-dehydroabietic acid
n-Valerylfuran	
thymol	
methyl dehydroabietate	
xylenol (2 isomers)	
trichlorophenol	
catechol	
trichloroguaiacol	
tetrachloroguaiacol	
dichloroacrylic acid	
C_{10} hydrocarbon	
α -phellandrene	
acetophenone	

* plus about 50 unknown compounds

Table 4. Compounds identified in fish livers from four stations and in sediment samples.*

	Station			
Sample Analysed	R1	R2N	R2S	R3
Sediment	diethylene glycol	diethylene glycol triethylene glycol 2-(2-methoxyethoxy)-ethanol tributyl phosphate dioctyl adipate 1-hydroxyisocarvomenthol 1-methyl-7-isopropyl-phenanthrene dehydroabietic acid	No sample	No sample
Largescale sucker	(1) diethylphthalate 2-methyldecalin (2 isomers) 2-pentylfuran	(2) diethyl phthalate	(2) diethyl phthalate unknown phenol 3 monoterpenes	No sample
Bridgelip sucker	(2) diethyl phthalate 2-methyldecalin	(1) dimethylphthalate diethyl phthalate tributyl phosphate unknown phenol	(2) diethyl phthalate tributyl phosphate 2 monoterpenes	(1) phenylacetic acid diethyl phthalate tributyl phosphate trimethyl phosphate dimethyl glutarate
Dolly Varden char	No sample	No sample	(2) trimethyl phosphate succinic acid phenylacetic acid N,N-diethylisopropylamine	succinic acid
Mountain whitefish	(1) unknown compounds giving strong m/e 45 peaks	Not analysed	(4) unknown compounds giving strong m/e 45 peaks	(1) clean

*Numbers in brackets indicate number of fish in sample.

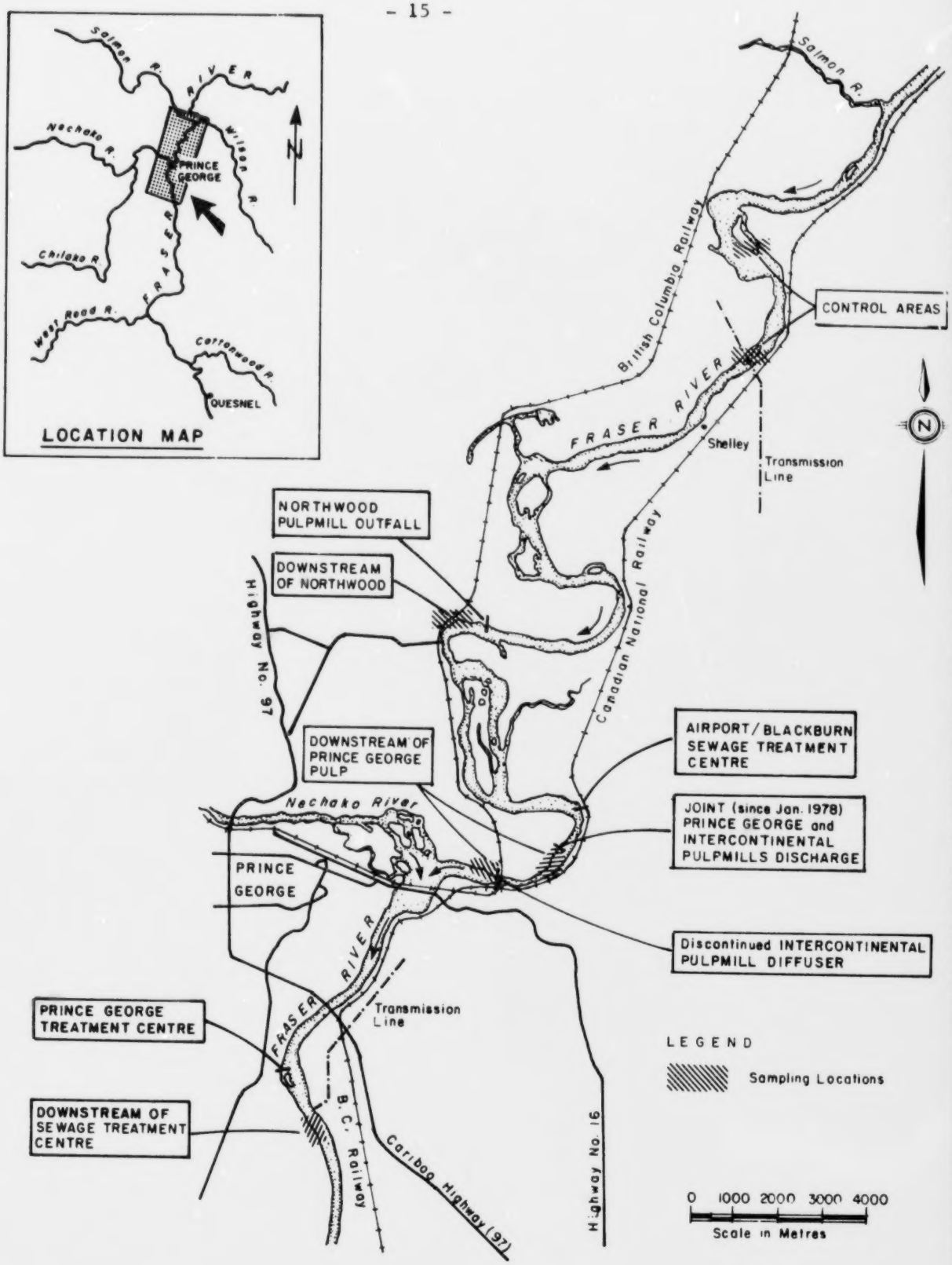

FIGURE 1 GENERAL LOCATION OF AREAS WHERE FISH AND SEDIMENT WERE COLLECTED